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CASE STUDY

The Challenge

Power electronic converters are the underpinning technology in modern electrical systems to achieve the Net Zero target in the energy and transportation sectors. As one of the fundamental passive components, power magnetics exist in almost all power converters and account for a significant impact on the volume, weight and power loss, e.g. 30%~50%. However, due to their nonlinear behaviours, the testing and modelling for power magnetics lag the development of power semiconductors, which has become the bottleneck for the virtual prototyping and design optimisation of power converters.

This project aimed at a paradigm shift in how power magnetics are tested and modelled towards a higher-level, component-based approach, which accounts for the geometry-related behaviour mechanisms that cannot be accurately predicted just from the material properties. As the key enabler, this project yielded a demonstrator to perform high-fidelity Triple Pulse Tests (TPT) as an open-source tool, which unlocks a rapid and in-situ testing capability for power magnetics. Secondly, a corresponding modelling method aided with machine learning (ML) techniques has been developed utilising the component-based data to form a full toolchain towards an accurate, user-friendly and data-driven 'testing and modelling' toolchain for power electronic engineers.

This project is a timely update for power magnetics to match how power devices are tested and modelled, which unlocks accurate co-optimisation with other parts of the converters and subsequently enables further performance exploitation of power converters on a system level.

Innovation

This project delivered a step-change in how power magnetics are characterised and modelled by creating, demonstrating, and disseminating the first high-fidelity, component-based Triple Pulse Test (TPT) toolchain. Addressing a long-standing limitation in the field—namely that magnetic components are still tested using small-signal, sinusoidal data that does not reflect real converter conditions—the project introduced an integrated, large-signal, waveform-accurate approach that enables engineers to measure losses under true operating stresses such as rectangular voltage excitation, DC bias, and large current swings

The technical innovation centred on two major developments:

An open-source automated TPT testbed (open TPT). The project systematically evaluated and solved measurement challenges resulting in a robust, high-voltage/high-current test system capable of rapid, in-situ and repeatable characterisation of magnetics in a cost-effective manner. This represents an advancement beyond commercial BH analysers.

A new modelling paradigm based on component-specific, data-rich “magnetics datasheets.”

The project produced a modelling tool and machine-learning-ready dataset structure that captures geometry-dependent behaviour—such as gap-related loss mechanisms—which cannot be predicted from material data alone. This enables fast, accurate, and user-friendly loss estimation directly from component measurements rather than legacy material-based equations.

Together, these advances pioneer a component-based approach for magnetics—similar to how power semiconductors are already treated—unlocking significantly improved accuracy, industry relevance, and pathways to standardisation. The work has already catalysed new industrial collaborations, open-source tools, follow-on proposals, and engagement with international standards bodies, demonstrating its transformative potential for the power-electronics community.

Result

This project delivered clear evidence that a component-based testing and modelling approach can dramatically improve the accuracy, repeatability and relevance of magnetic loss characterisation for

power-electronics applications. By developing the open-source TPT testbed and validating it against existing approaches, the project demonstrated that large-signal, waveform-accurate testing reveals loss behaviours that conventional sinusoidal, material-based data systematically miss. This confirms that many discrepancies previously attributed to modelling limitations are in fact rooted in insufficient or unrepresentative measurement methods.

A second key insight was the value of “rich,” data-driven magnetics datasheets. The project showed that geometry-dependent effects—such as gap losses and flux non-uniformity—can be reliably captured and modelled when high-quality component-specific datasets are available. This provides a practical pathway for engineers to estimate losses quickly and accurately without relying on legacy empirical equations.

Beyond the technical findings, the project generated strong evidence of sector appetite and readiness for this approach. Concrete results include:

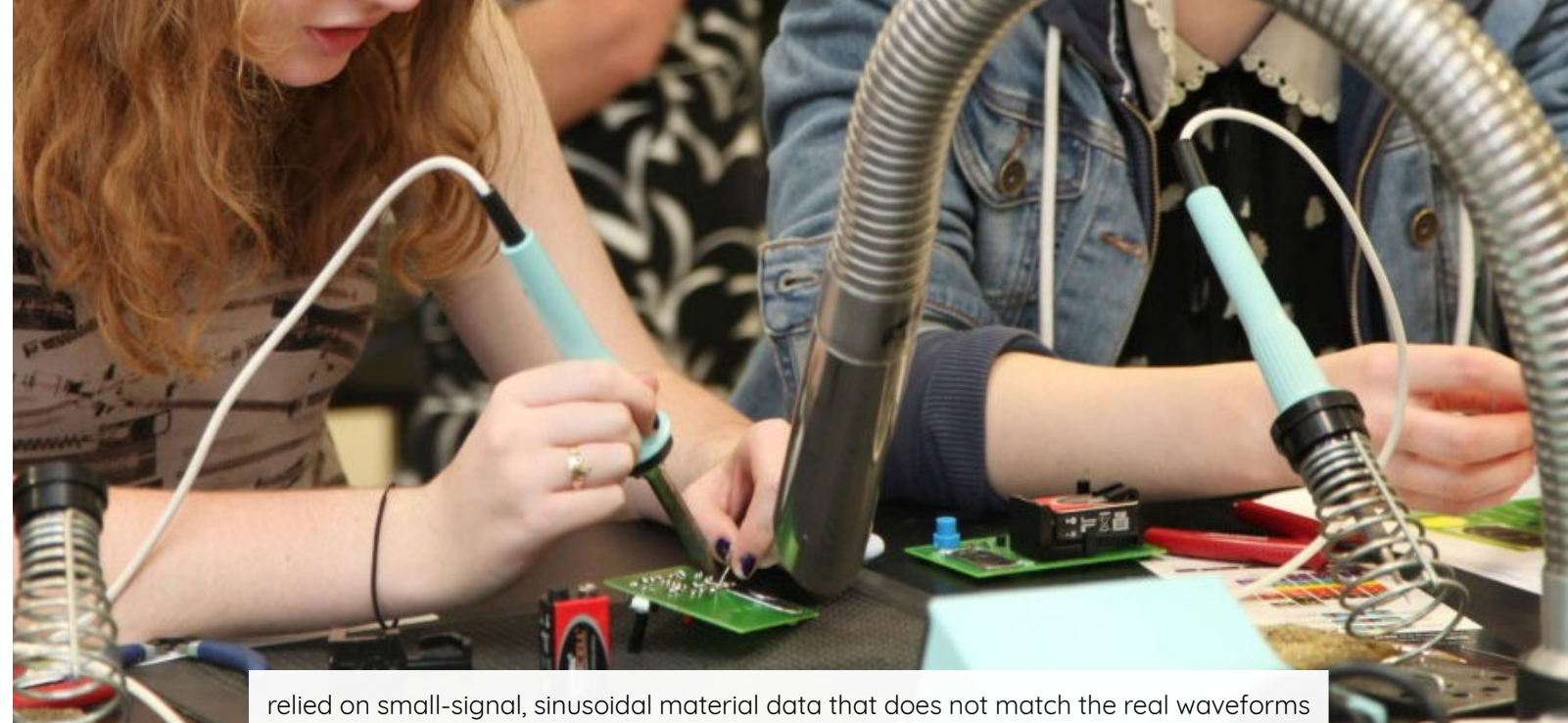
- Two major funding proposals submitted
- One conference paper and one journal paper published.
- Two open-source projects released on GitHub.
- Two invited industry-facing talks, including at PSMA/APEC.

Together, these results highlight both the technical validity and the strong industrial pull for next-generation, component-based magnetics characterisation.

Impact

This project has created the foundations for a major shift in how the power-electronics sector tests, models, and ultimately designs magnetic components. By delivering a verified, high-fidelity Triple Pulse Test (TPT) method and an accompanying data-driven modelling workflow, the work removes one of the most persistent bottlenecks in power-converter development: the lack of accurate, component-specific magnetic loss data under real operating conditions.

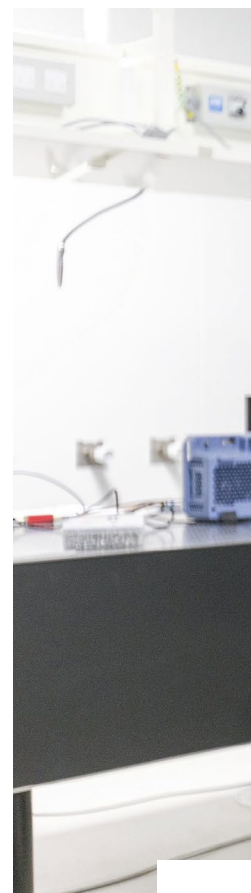
Accurate magnetics data directly influences converter efficiency, power density, thermal design, and cost. Until now, engineers have



relied on small-signal, sinusoidal material data that does not match the real waveforms used in modern systems. This project provides—for the first time—a practical, scalable way to measure losses exactly as they occur inside a converter. This closes a long-standing knowledge gap and enables designers to unlock significant performance gains with more confidence and less trial-and-error. The approach has the potential to reshape engineering practice across the magnetics supply chain:

- Component manufacturers can use TPT to generate richer, more relevant datasheets, improving product transparency and competitiveness.
- Testing-equipment suppliers gain a new blueprint for next-generation instrumentation.
- End users (automotive, aerospace, energy) can rapidly model designs with higher accuracy, enabling more efficient, lighter and more compact power-electronics systems.

The project enabled an open-source TPT platform for broad community uptake. Together, these pathways position the innovation for global adoption, enabling widespread improvements in magnetics characterisation and accelerating progress toward higher-efficiency, net-zero-aligned power-electronics technologies.



Jun Wang

“We’ve transformed how magnetic components can be tested and understood—shifting from material-based guesses to component-based truth—and enabling faster innovation and better-performing power converters across industry.”

CSA Catapult

“The partnership between Jun and CSAC exemplifies how academic innovation and Catapult expertise can accelerate the adoption of next-generation testing methods, supporting the UK’s net-zero ambitions and strengthening the power electronics ecosystem.” - Ingo Ludtke
Head of Power Electronics at CSA Catapult.